

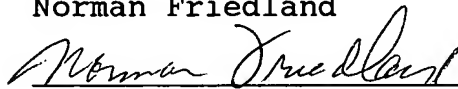
N1087

**U.S. PATENT APPLICATION OF**  
**ALFRED PAUL METHENY**

relating to  
**CONSTRUCTION OF STATIC STRUCTURES FOR GAS TURBINE ENGINES**

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Norman Friedland



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## **Description**

### **CONSTRUCTION OF STATIC STRUCTURES FOR GAS TURBINE ENGINES**

#### **Federally Sponsored Research**

5                      **None**

#### **Technical Field**

This invention relates to static structures in gas turbine engines and more particularly to these structure that are fabricated from foam metal material and judiciously coated.

#### 10                      **Background of the Invention**

As is well known in the power plant technology, one of the more insidious problems associated with gas turbine engines and particularly those powering aircraft is the structural damage such as cracking of the components that operate in these hostile environments. Needless to say, because of the  
15                      enormous costs in original and replacement components like vanes and seals, there is a tremendous need in the industry to provide a suitable material that

minimizes the repair technique that will not only serve to repair the damaged component, but also to add life to these components and improve performance.

5 The turbine power plant typically consists of an air inlet, a fan/compressor section, a diffuser, a combustor, a turbine section and an exhaust nozzle. In military engines an afterburner or augmentor may be located just downstream of the turbine section and ahead of the exhaust nozzle. The air from the inlet is pressurized by the compressor and it is then diffused and admitted to the combustor where fuel is added and combusted  
10 to accelerate and heat the air so that the combined combusted products serve to power the turbines. A portion of this energy is used to develop thrust and another portion is used to power the fan/compressors. Inasmuch as the heat generated in the power plant is sufficiently hot to impair the structural integrity of the engine components, air, typically from the compressor section, is  
15 utilized to cool certain engine components

Hence, not only is the engine subjected to extreme temperatures and high stress levels, it is also subjected to foreign matter that is ingested in the inlet of the engine. All of these conditions play an extremely important role in

the selection of the material and design of the power plant. One of the concerns with respect to this invention is the propensity of cracks that can occur in certain static engine components and the economics of the original parts as well as the repair and replacement of parts. In heretofore known materials being utilized in current day engines, a crack or crevice developed in a component tends to propagate and if not attended to within a given time period, this part can lead to a failure of the part and ultimately to an engine failure. Another concern is that the coating of engine components during the normal operation of the engine has a tendency to degrade or peel off. Hence, the gases that pass through the engine also include particles of sand, dust oxides of calcium, magnesium, aluminum, silicon and mixtures. The oxides can combine to form particularly deleterious calcium-magnesium-aluminum-silicon oxide systems. These contaminants can be in a molten state and can infiltrate pores and openings in engine parts that can lead to crack formation and part failure. The severity of the problem is manifested because the substrate is generally formed from a metallic smooth surface. Hence, the combined fight between the thermal loads and the stress in addition to the bond strength acerbate the problem so that the coating tends to peel rather

than remain local. This limits the effective thickness that the TBC can be used which, in turn, sets the cooling requirement and engine performance. The thicker coating allows lower cooling and hence, enhances performance. It is therefore the goal of the engine designer to provide components that have  
5 long life, effective thickness, are economical, maintainable and meet engine specification requirements to achieve the ultimate in gas turbine engine efficiency.

Porous metal material, sometimes referred to as foam metal, has been to some degree developed and is currently undergoing development and  
10 exhibit properties that could be adapted for engine use. Such foam metals are fabricated by mixing metal particles with a pliable organic hollow spheres into a liquid as a suspension. There after the solution is processed by pressing, slip casting, extruding or injection molding the mixture and then dried. The now dried material is fired to bond the particles such as by sintering so as to  
15 eliminate the organic spheres. A good understanding of the manufacturing of foam metals can be had by referring to U. S. Patent No. 5,937,641 granted to Graham et al on August 17, 1999 and U. S. Patent No. 6,592,787 granted to Pickrell, et al on July 15, 2003, both of which are incorporated herein by

reference.

5 This invention solves the problem of providing certain engine component parts, namely the outer air seal for the turbine and the stator vanes, by fabricating these components from a foam metal, coating the same with a suitable thermal barrier or ceramic coating and judiciously locating openings in the components for cooling purposes so as to withstand the temperatures of the hostile environment. According to this invention the problem of cracking and coating peeling is either eliminated or significantly reduced. When the component is injured where a blemish, crack or crevice is formed on the surface of the part, the material is such that the propensity for the blemish, crack or crevice to propagate is eliminated so that the repair process is significantly enhanced.

10

#### **Summary of the Invention**

15 An object of this invention is to fabricate static power plant components from a foam metal, coat the same with a thermal barrier or ceramic coating and include air inlet or exit openings to cool the parts internally. Letting the cooling air discharge from the coating as it migrates

thereto through the porous metal serves to provide transporational cooling of the exterior surface of the coating.

Another object of this invention is to fabricate an outer air seal for a gas turbine engine from a foam metal, coat the same with a thermal barrier or ceramic coating and include air inlet or exit openings to cool the parts internally.

Another object of this invention is to fabricate the vanes of a stator vane for a gas turbine engine from a foam metal, coat the same with a thermal barrier or ceramic coating and include air inlet openings to cool the parts internally.

The foregoing and other features of the present invention will become more apparent from the following description and accompanying drawings.

#### **Brief Description of the Drawings**

Fig. 1 is a fragmentary view partly in section and partly in elevation of the outer air seal for the turbine blades in the turbine section of a gas turbine engine showing the details of this invention;

Fig. 2 is an enlarged perspective view of a section of the segmented

or ring outer air seal of Fig. 1;

Fig. 3 is a fragmentary view partly in section and partly in elevation showing the details of this invention in the vane portion of the stator vane for a gas turbine engine; and

5 Fig. 4 is a sectional view showing the details of this invention taken along lines 4-4 of Fig. 3.

Fig. 5 is a fragmentary view of the coated porous metal to illustrate the transpirational cooling attained by this invention.

These figures merely serve to further clarify and illustrate the present  
10 invention and are not intended to limit the scope thereof.

### **Detailed Description of the Invention**

While the preferred embodiment of this invention is directed to bladed outer air seals, sometimes referred to as BOAS, and vanes of a stator vane  
15 assembly for gas turbine engines, as one skilled in this art will realize, other components of the gas turbine engine may lend themselves to utilize the invention. What is deemed important in this invention is that the substrate has minute holes that serve as a bond or integral bond of the coating so that the

coating does not have a tendency to peel and hence, the crack or blemish stays localized to enhance the repair of the part. Additionally, the particular coating material and the method of application that is utilized may vary from component to component and for various engine applications. The coatings  
5 referred to in this patent application are well known coatings utilized in turbine power plant technology and any appropriate state-of-the art coatings utilized with this invention are deemed to be within the scope of this invention. As one skilled in this art will realize, while the construction of the vanes of a stator vane assembly and outer air seals are novel and not obvious,  
10 these components are mere examples of how this invention can be applied in a gas turbine engine and hence, for the lack of another description, they serve as examples of this invention.

The first part of this description refers to the outer air seal (BOAS) generally illustrated by reference numeral 10 for the turbine of a gas turbine engine (not shown) and depicted in Figs. 1 and 2 as comprising the outer air  
15 seal main body 12 supported to the engine case 14 and surrounding the axial flow turbine rotor assembly 15 consisting of blade 16 (only one of several circumferentially spaced blades is shown). The turbine blade is suitably

mounted to the disk 18 which, in turn, is coupled to the engine shaft (not shown) for rotary motion. Ahead of and in back of the turbine blade 16 are the stator vane assemblies 20 and 22, respectively and each stator vane assembly includes a plurality of circumferentially spaced vanes 24 and 26 (only one being shown) that serve to direct the engine working medium into adjacent turbine blades.

These components are well known and for more details thereof reference should be made to U. S. Patent No. 6,393,331 granted to Chetta et al on May 21, 2002 and U. S. Patent No. 5,839,878 granted to Maier on November 24, 1998. Suffice it to say that this invention is particularly concerned with static structures in the engine where it is desirable to provide a component that is characterized as being capable of withstanding the high temperatures and hostile environment while affording the advantages being described herein. In the BOAS the outer air seal main body is made from a high temperature porous material, like a foam metal such as that manufactured by Porvair Advanced Materials, 700 Shepherd Street, Hendersonville, North Carolina 26792 USA that could be made from Hastalloy, Inconel, FeCRAlly and the like. The material selected must be capable of being reduced to a

powder so that it can be processed into a porous material that exhibits a low density high strength structure. As noted from Figs. 1 & 2 the outer air seal 10 is a ring-like structure that includes the hook members 30 and 32 that fit into a complementary groove 34 and 36 respectively and the ring-like structure may be a complete 360° ring, 180° rings or it may be segmented into a number of segments to form the ring. The outer air seal main body consists of the shaped porous member 40 and the coating 42. The coating may be any well known thermal barrier coating (TBC) or ceramic coating that is capable of withstanding the temperature environment of the engine. Various coating process may be utilized as for example, plasma spray, chemical vapor deposition, physical vapor deposition or reactive coatings. Standard surface preparations required for each of these processes may be utilized. For more details of these types of coatings reference should be made to U. S. Patent No. 5,272,014 granted to Leyendecker on December 1993, and U. S. Patent No. 5,656,364 granted to Rickerby on August, 1997, U. S. Patent No. 5,702,829 granted to Paidassi on December, 1997, U. S. Patent No. 4,588,450 granted to Purohit on May 1986 And U. S. Patent No. 6,129,988 granted to Vance et al on October, 2000 all of which are incorporated herein

by reference.

In order to assure the structural integrity of the BOAS, a plurality of openings 68 formed on the outer face that serve to receive cooling air and admit the air internally of the porous metal where the air migrates through the metal to cool the component.

Another component that lends itself to utilizing porous metal or foam metal is the vane 70 (one of a plurality of circumferentially spaced vanes being shown) of the stator vane assembly 72 depicted in Figs. 3 and 4. The vane assembly 72 may be fabricated by a plurality of single vanes 70 attached to an upper platform or shroud 76 and a lower platform (not shown) or may consist of a plurality of segmented vanes mounted in the platforms and attached to form the ring construction. These techniques are well known in this technology and like the BOAS, this invention is directed to the structure of the main body of the vane 70. This member utilizes the same types of foam metal 78 and coating 80 that is described in the embodiment depicted in Figs. 1 and 2. For the sake of simplicity and convenience, a description thereof is omitted and the details are incorporated herein by reference. Similar to the BOAS, a plurality of openings 82 formed on the outer face that serve to

receive cooling air and admit the air internally of the porous metal where the air migrates through the metal to cool the component assuring that the component is cooled so as to maintain its structural integrity.

5 Fig. 5 is exemplary of the option of designing the coating so that it provides transpirational cooling such that the foam metal that is subjected to cooling air, as air from the compressor, for example, flows through the minuscule pores of the porous metal 80 and into the apertures 90 formed in the coating. The pressure ratio of the air across the coating is designed so that the aperture 90 produces film cooling whereby the air discharging from  
10 aperture 90 flows along the surface of the coating and hence provides another cooling from the spent air used to cool the porous metal.

What has been shown by this invention is the static structure of a gas turbine engine capable of operating in the high temperature hostile environment and characterized by providing a coating that when blemished  
15 or cracked the propensity of the blemish or crack of propagating is if not eliminated, is reduced, because the bond of the coating adheres to the minute interstices of the porous material. Hence, the problem of the coating peeling from the substrate is minimized or eliminated.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be appreciated and understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention.

5      It is claimed: